NWC TP 5786

Safety Evaluation Tests of Conductive Floor Coatings for Ordnance Facilities

by

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Safety Department

SEPTEMBER 1975

Naval Weapons Center
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center

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FOREWORD

This report summarizes the results of approximately two years of tests conducted at the Naval Weapons Center to study the effectiveness of conductive coatings on floors in areas involving the processing, handling, and storing of high-energy materials.

The work covered by this report was funded in part by Propulsion Development Department safety overhead funds and was carried out primarily during the period of March 1973 to April 1975.

This report was given technical review by Paul A. Donaldson of the Safety Department and Glenn R. Johnson of the Propulsion Development Department.

Released by
PAUL A. DONALDSON, *Head*
Explosives Safety Division
1 August 1975

Under the authority of
K. S. SKAAR, *Head*
Safety Department

NWC Technical Publication 5786

Published by .... Technical Information Department

Collation .... Cover, 15 leaves

First printing .... 100 unnumbered copies

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NWC TP 5786	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SAFETY EVALUATION TESTS OF CONDUCTIVE FLOOR COATINGS FOR ORDNANCE FACILITIES		5. TYPE OF REPORT & PERIOD COVERED Summary; March 1973 to April 1975
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Glenn Pritchard		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Weapons Center China Lake, CA 93555		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Weapons Center China Lake, CA 93555		12. REPORT DATE September 1975
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Electrically Conductive Flooring
Electrically Conductive Floor Coatings

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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S/N 0102-014-6601

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Safety Evaluation Tests of Conductive Floor Coatings for Ordnance Facilities, by Glenn Pritchard. China Lake, Calif., Naval Weapons Center, September 1975. 28 pp. (NWC TP 5786, publication UNCLASSIFIED.)

This report assembles and summarizes the results of tests conducted for two years at the Naval Weapons Center to study the effectiveness and suitability of electrically conductive coatings (paints, cleaners, and toppings) on floors in areas where work on propellants, high explosives, pyrotechnics, and other high-energy materials is involved. Criteria used to evaluate the coatings are discussed, in addition to the advantages and limitations of each of the coatings. Variables to be controlled in future tests are also discussed.

CONTENTS

ACKNOWLEDGMENT

Appreciation is expressed to the following members of the Propulsion Development Department Conductive Floor Working Group for their cooperation and interest shown in the support of these conductive coating evaluations: Dura Pinkerton, Glenn Johnson, Richard Printy, Paul Donaldson, Michael Osburn, William Francis, and Paul Rivette.

INTRODUCTION

Current regulations require the use of electrically conductive flooring at ordnance and explosive research facilities to prevent accidental initiation of high-energy materials. To comply with the regulations ordinary floors may need to be made electrically conductive and those floors that are already electrically conductive must be satisfactorily maintained. However, malfunctions of conductive flooring occasionally occur. Age, attrition, soaps not specifically designed to retain conductivity, and wax carried on mobile equipment or the shoes of personnel are usually responsible for electrical resistance readings in excess of the maximum acceptable NAVSEA requirement of 1,000,000 ohms. When resistance is too high, static electricity can accumulate, and exposed explosives, propellants and pyrotechnics, flammable mixtures of solvents and air, and electroexplosive devices can be initiated by energy released from this static accumulation. Conversely, condensation under and on top of floors or excessive conductive elements in the floor are usually responsible for electrical resistance readings below the minimum acceptable NAVSEA requirement of 5,000 ohms for 110-volt service and 10,000 ohms for 220-volt service. When resistance is too low, the potential for electrical shock increases.[1] (NFPA requirements prohibit a resistance of less than 25,000 ohms regardless of voltage.)[2]

In each of the above situations there may not be sufficient time or money available to install new conductive flooring; therefore conductive coatings such as paints, cleaners, and toppings must be substituted to bring the resistance readings to a safe level.[3,4]

This report summarizes the results of a study involving a select group of conductive coatings evaluated over a two-year period in the Propulsion Development Department at the Naval Weapons Center. Primarily, it is concerned with the effectiveness with which coatings meet conductive flooring specifications. Appendix A gives these specifications in greater detail. In addition, it is the intent of this report to show that some coatings can be substituted for actual conductive flooring, especially where limited time and money is a factor. Finally, the report is used as a vehicle for the discussion of a number of important variables needing control in future electrically conductive coating evaluations.

[1] Naval Sea Systems Command. *Ammunition and Explosives Ashore, Safety Regulations for Handling, Storing, Production, Renovation and Shipping. Volume 1.* (NAVSEA OP-5, Vol. 1, Fourth Revision, 15 October 1974.)

[2] National Fire Protection Association. *Standard for the Use of Inhalation Anesthetics.* Boston, Mass. 1970. (Standard No. 56A.)

[3] Naval Civil Engineering Laboratory. *Conductive Flooring for Ordnance Activities and Hospitals*, by Peter J. Hearst, Port Hueneme, Calif., NCEL, June 1972. (Technical Note N-1235, publication UNCLASSIFIED.)

[4] Naval Civil Engineering Laboratory. *Electrical Resistance Measurement of Conductive Flooring*, by Peter J. Hearst, Port Hueneme, Calif., NCEL, June 1973. (Technical Note N-1289, publication UNCLASSIFIED.)

METHOD

Limited funding and time precluded extensive small-scale laboratory analysis on the numerous conductive coatings currently available on the market. Consequently, six coatings considered to be more desirable than others were selected for evaluation. These were Groundzol #6890, Elimstat LX-23, Phenoline 304 Conductafloor, Conducote (all conductive paints), Legclean (conductive cleaner), and Cheminert (conductive topping). A listing of the addresses of the manufacturers of the coatings evaluated is given in Appendix B. The use of the aforementioned trade names in this report is for identification purposes and does not constitute an endorsement of the products so named.

A number of criteria were used in this report to evaluate each coating, either during its initial selection or subsequent use. Following is a list of these criteria, not necessarily in order of importance.

1. The coating must be acceptable from a cost (material and labor) standpoint.
2. It must be compatible with modern day explosives, propellants, pyrotechnics, and other high-energy materials.
3. It must easily be mixed and applied.
4. It must provide the necessary and acceptable resistance requirements, as specified by NAVSEA.[1]
5. It must bond or adhere properly.
6. It must exhibit nontoxic properties.
7. It must be able to withstand pedestrian and materials loading traffic over an acceptable time period.
8. It must accept the inadvertent spillage of cleaning or thinning solvents without significant physical deterioration.
9. It must withstand washing with water or detergent.
10. It must have the desired color.
11. It must exhibit nonsparking characteristics.

Fifteen rooms in explosive operating buildings of the Propulsion Development Department were selected for evaluation (Appendix C). Each room was typical of those found in explosive facilities. All rooms evaluated had concrete floors. Resistance measurements were made with a 500-volt DC ohmmeter (Figure 1) at six carefully selected places on the floor of each room evaluated. These places remained unchanged during the two-year evaluation period.

The procedures outlined in Appendix A were followed during the entire evaluation period. However, two test limitations should be acknowledged at this time. Present testing requirements call for both electrode-to-electrode (Figure 2) and electrode-to-ground (Figure 3) measurements. When some of the coatings were originally evaluated, it was not known that both measurements were required. Therefore in earlier cases resistances reflect only one or the other of these measurements.

Nonresilient electrodes (i.e., those without a surface of tinfoil, backed by a layer of rubber) were used for all tests. Current resistance measurement requirements specify the use of resilient electrodes.

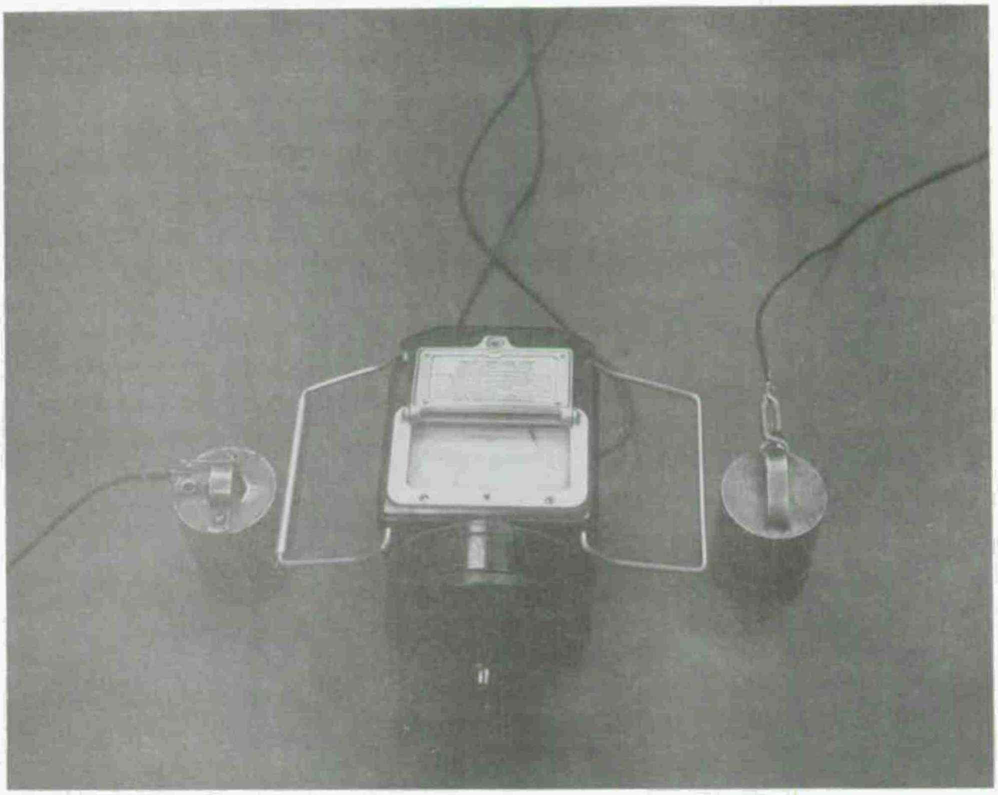

FIGURE 1. 500-Volt DC Ohmmeter and Electrodes Used During All Conductive Coating Evaluations.

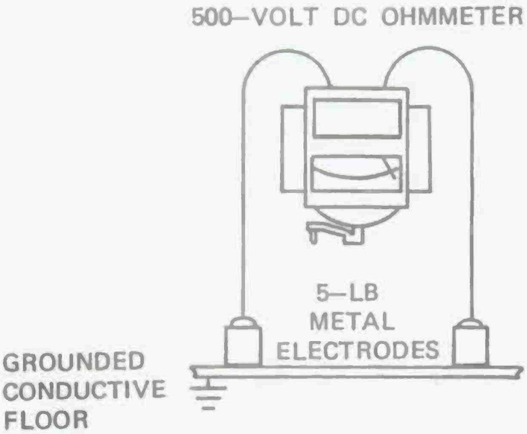

FIGURE 2. Testing Grounded Conductive Floors Using Electrode-to-Electrode Measurements (3-Foot Separation).

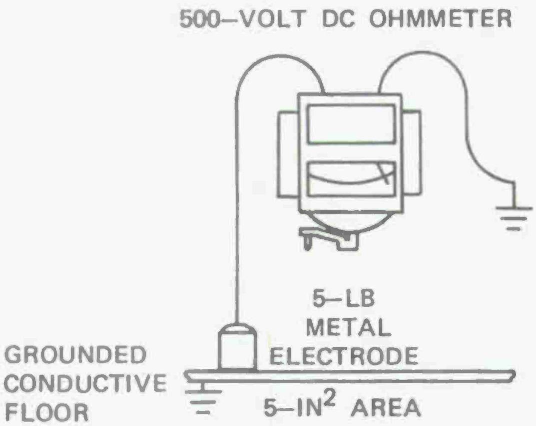

FIGURE 3. Testing Grounded Conductive Floors Using Electrode-to-Ground Measurements.

RESULTS

The results of the six coatings evaluated have been divided into three categories for ease of comparison: (1) conductive paints, (2) conductive cleaners, and (3) conductive toppings. Described below in narrative fashion, the results are also listed in tabular form in Appendixes D through F. A list of nomenclature used in the text is provided at the end of the report.

CONDUCTIVE PAINTS

Groundzol #6890

Groundzol, an easily mixed and applied conductive coating, is an aluminum-colored paint with acceptable nonsparking characteristics (Figure 4). The cost and nontoxic properties were found to be acceptable. The coating, since initial evaluation, has been found to be durable under light and heavy pedestrian and materials loading traffic. Wet and dry mopping, when done moderately, appear to have no significant adverse effect.

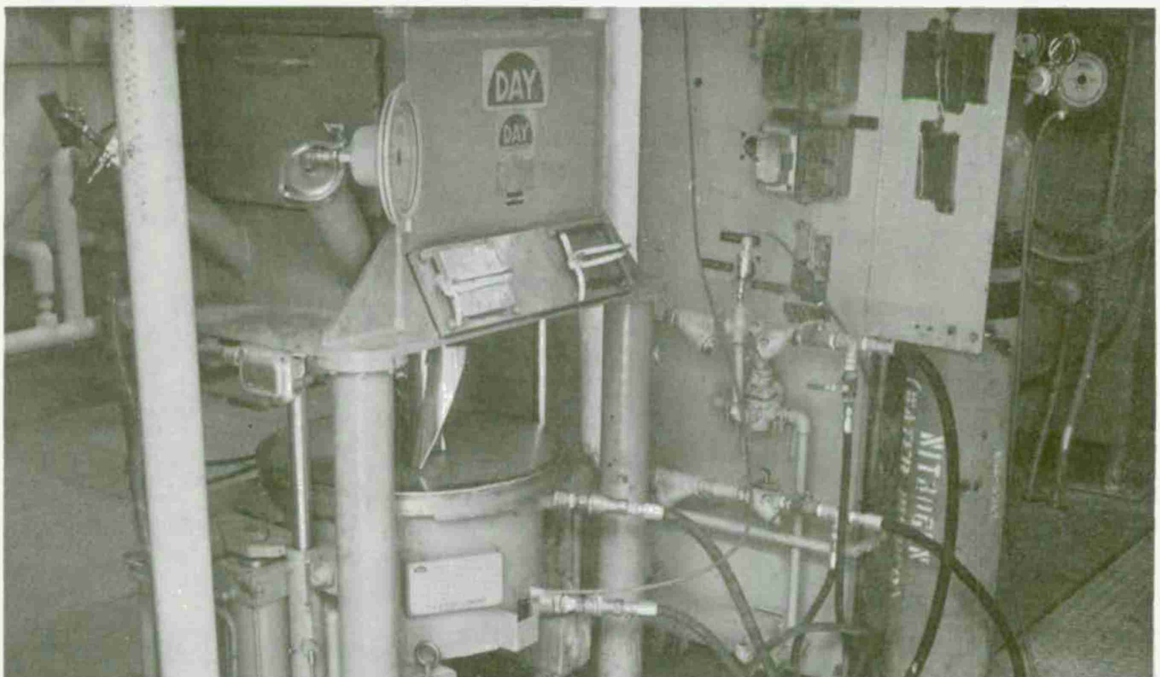

FIGURE 4. Groundzol Conductive Coating in a Typical Mixing Bay. Coating is applied to the nonskid metal plates as well as to the floor.

It can readily be seen from the available data that Groundzol was effective in lowering the floor resistance of all ordnance buildings evaluated. Table 1 shows that the average resistance reduction achieved by Groundzol ranged from a low of 75% to a high of 99.93%. These values were obtained by determining the resistance reading prior to the application of the floor coating, subtracting the resulting values obtained after coating application, and then calculating the percent of

TABLE 1. Average Resistance and Resistance Reduction Achieved by Groundzol #6890 Floor Paint.

Location[a]	Average[b] resistance, ohms	Average resistance[c] reduction, %	Type of Measurement[d]		
			Before application	At application	After application
1	100M	. . .	E-G	. . .	. . .
	108K	99.89	. . .	E-G	. . .
	458K	98.54	. . .	. . .	E-E
	110K	99.89	. . .	. . .	E-G
2	100M	. . .	E-G	. . .	. . .
	225K	99.78	. . .	E-G	. . .
	200K	99.80	. . .	. . .	E-G
3	42M	. . .	E-G	. . .	. . .
	1.6M	96.19	. . .	E-E	. . .
	296K	99.29	. . .	E-G	. . .
	700K	98.33	. . .	. . .	E-E
	188K	99.53	. . .	. . .	E-G
4	1M	. . .	E-G	. . .	. . .
	250K	75.00	. . .	E-E	. . .
	75K	92.50	. . .	E-G	. . .
	167K	83.30	. . .	. . .	E-E
	71K	92.90	. . .	. . .	E-G
5	960K	. . .	E-G	. . .	. . .
	54K	94.38	. . .	E-G	. . .
	128K	86.67	. . .	. . .	E-E
	83K	91.35	. . .	. . .	E-G
6	41M	. . .	E-G	. . .	. . .
	318K	99.22	. . .	E-G	. . .
	7M	82.93	. . .	. . .	E-E
	724K	98.23	. . .	. . .	E-G
7	100M	. . .	E-G	. . .	. . .
	350K	99.65	. . .	E-G	. . .
	258K	99.74	. . .	. . .	E-E
	71K	99.93	. . .	. . .	E-G

[a] See Appendix C for corresponding building and room locations.
[b] Average of readings for six places in room. See Appendix D for raw data. M = 1,000,000 ohms; K = 1,000 ohms.
[c] The difference in resistance readings before and after application of floor coating is determined, then the percent of resistance reduction is calculated.
[d] E-G, electrode-to-ground measurement; E-E, electrode-to-electrode measurement.

reduction. The higher the percent of reduction, the more effective the conductive coating was in reducing resistance values. The actual test data can be found in Appendix D. From this data it can be seen that the higher the initial floor resistance prior to the application of the coating, the more drastic the drop differential in resistance after application. Readings greater than 100,000,000 ohms were reduced, in some cases, to 50,000 ohms. In other instances, readings approximating 1,000,000 to 50,000,000 ohms were reduced to 10,000 ohms.

Another interesting aspect of this data is in the area of measurement. Electrode-to-ground measurements were invariably lower than electrode-to-electrode (3 feet separation) measurements. Differences as much as 100,000 ohms were observed. Table 1 shows that the average resistance reductions were less with the electrode-to-electrode measurement than with the electrode-to-ground measurement.

Acid etching (50% hydrochloric acid and 50% water) of some of the floors prior to the coating application also appeared to be a factor in lowering resistance, possibly due to the better bonding surface created by the acid etching. Heavy pedestrian and materials loading traffic appeared to affect the coating more than moderate or light traffic. Resistance readings were, in most cases, higher after about a year of heavy traffic; this occurred both with electrode-to-electrode and electrode-to-ground measurements.

In a thermogram analysis, Groundzol, was shown to be compatible with C-518 propellant (AP/A1/CTPB), PBXN-5 explosive (HMX/Viton), and Composition B explosive (RDX/TNT). Decomposition peaks and exotherms were not significantly different when each propellant or explosive material was analyzed with the coating and alone.

The only problem with the Groundzol coating appears to be blemishes and bubbling on the coating surface after extensive contact with acetone or steam. Since most explosive research facilities do not expose flooring to such extensive contact with steam or acetone, the Propulsion Development Department has found the product to be acceptable.

Elimstat LX-23

Elimstat is a grayish-black paint with acceptable nonsparking characteristics (Figure 5). It is easily mixed and easily applied onto existing floors. The cost is acceptable, and toxic characteristics are negligible. The coating appears to be durable under light and heavy pedestrian and materials loading traffic. Moderate wet and dry mopping appear to have no effect on its durability.

As can be seen from Table 2, Elimstat was effective in lowering the resistance of building floors. Table 2 shows that the average resistance reduction achieved by Elimstat ranged from a low of 93% to a high of 99.99%. The actual test data is given in Appendix E. From this data it can be seen that electrode-to-electrode and electrode-to-ground measurements in practically every case registered between 10,000 and 50,000 ohms even after as much as a year's usage of the coating.

Again, electrode-to-ground measurements were lower than electrode-to-electrode measurements, but the difference was not as much as that found with the Groundzol coating.

Traffic appeared to have little effect on the conductive coating, both from a resistance and an endurance viewpoint.

In an 80°C oven-heat analysis, Elimstat was found to be compatible with RDX and AP. However, this same analysis did show a reddish change when TNT and the conductive coating were placed in contact. (Color changes of any kind indicate that there has been a chemical reaction that could indicate an incompatibility with a hazardous material.) Consequently, Elimstat was not used or evaluated in the Propulsion Development Department's TNT facilities.

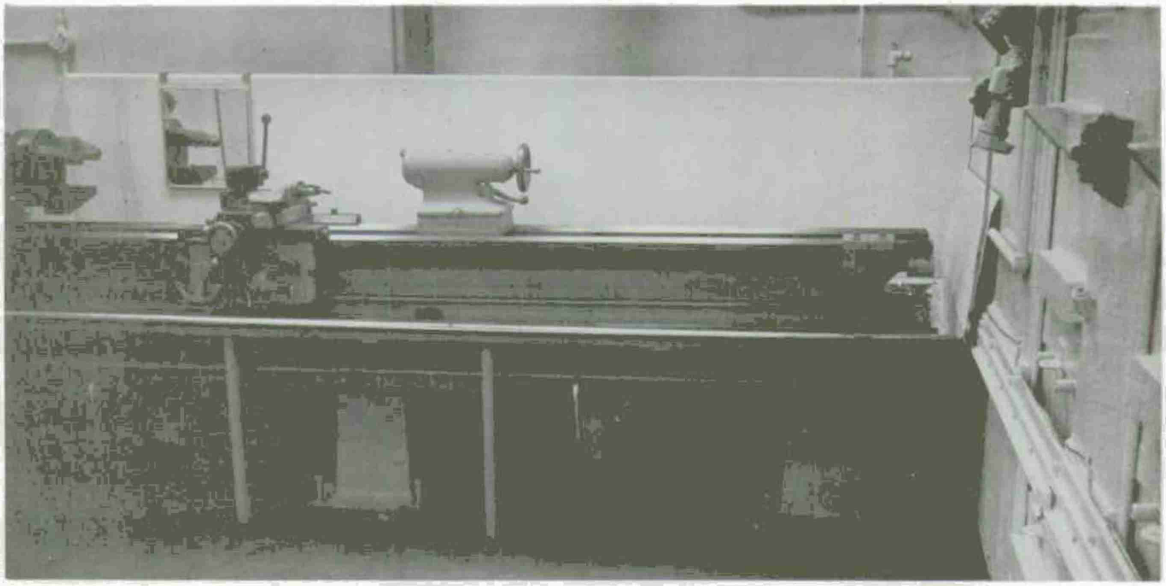

FIGURE 5. Elimstat Conductive Coating in a Typical Machining Bay.

Elimstat exhibited several other problems. Acetone and steam each caused significant blemishing and bubbling, very similar to the effect on Groundzol. Water left standing on the coating and then mopped up vigorously caused peeling of the coating. The resistance provided by this coating may be unacceptably low as specified in NAVSEA.[1] There appears to be no acceptable way to adjust coating resistance by varying coating thickness.

Conducote

The Propulsion Development Department did not find this product acceptable because the additional costs involved with using Thinner Hex (a thinner for the Conducote) and Conducote Finish (a topping for the Conducote) made the coating too expensive. Therefore the only evaluations made of Conducote were the cost, ease of mixing, method of application, and color.

Phenoline 304 Conductafloor

Conductafloor is black and has acceptable nonsparking characteristics. The cost, however, was found to be unacceptable. The requirement for a solvent, Phenoline 305 concrete primer, and a conductive tape used around the perimeter of the floor, in addition to the Phenoline 304 Conductafloor made purchasing this coating financially prohibitive. Limited tests were performed using one-gallon samples of Phenoline 304 and 305.

Using the 80°C oven-heat analysis, compatibility information was acquired. The Phenoline 304 Conductafloor was found to be compatible with RDX and AP, but reacted immediately with TNT to create a distinctive yellow discoloration. The Phenoline 305 concrete primer, originally yellow, turned reddish-brown after overnight oven evaluation. TNT and AP both caused the primer to immediately turn blood red and red, respectively.

Although no actual resistance measurements were performed, company literature indicates that resistance will vary in direct proportion to the thickness of the coating. The effects of traffic, detergent cleaning, and solvent use were not evaluated.

TABLE 2. Average Resistance and Resistance Reduction Achieved by Elimstat LX-23 Floor Paint.

Location[a]	Average[b] resistance, ohms	Average resistance[c] reduction, %	Type of Measurement[d]		
			Before application	At application	After application
1	100M	. . .	E-E	. . .	. . .
	10K	99.99	. . .	E-E	. . .
	10K	99.99	. . .	. . .	E-E
	10K	99.99	. . .	. . .	E-G
2	100M	. . .	E-G	. . .	. . .
	10K	99.99	. . .	E-G	. . .
	53K	99.95	. . .	. . .	E-E
	15K	99.99	. . .	. . .	E-G
3	100M	. . .	E-E	. . .	. . .
	100M	. . .	E-G	. . .	. . .
	10K	99.99	. . .	E-E	. . .
	10K	99.99	. . .	E-G	. . .
	47K	99.95	. . .	. . .	E-E
	10K	99.99	. . .	. . .	E-G
4	100M	. . .	E-E	. . .	. . .
	83M	. . .	E-G	. . .	. . .
	10K	99.99	. . .	E-G	. . .
	53K	99.95	. . .	. . .	E-E
	10K	99.99	. . .	. . .	E-G
5	100M	. . .	E-G	. . .	. . .
	10K	99.99	. . .	E-G	. . .
	20K	99.98	. . .	. . .	E-E
	10K	99.99	. . .	. . .	E-G
6	1M	. . .	E-G	. . .	. . .
	10K	99.00	. . .	E-G	. . .
	70K	93.00	. . .	. . .	E-E
	30K	97.00	. . .	. . .	E-G

[a] See Appendix C for corresponding building and room locations.
[b] Average of readings for six places in room. See Appendix E for raw data. M = 1,000,000 ohms; K = 1,000 ohms.
[c] The difference in resistance readings before and after application of floor coating is determined, then the percent of resistance reduction is calculated.
[d] E-G, electrode-to-ground measurement; E-E, electrode-to-electrode measurement.

CONDUCTIVE CLEANERS

Legclean

Legclean, a liquid nontoxic floor cleaner, is a clear cleaner usually mixed with water in various parts and designed to be effective in restoring floor resistance in floors slightly above the acceptable 1,000,000-ohm-level. As a cleaner Legclean is designed to provide considerable monetary savings, compared to the cost of floor replacement or coating additives. Table 3 shows that the average resistance reduction achieved by Legclean ranged from 99.72 to 99.90%. The raw data is available in Appendix F. Electrode-to-electrode measurements again were higher than electrode-to-ground measurements.

In an 80°C oven-heat analysis, Legclean was found to be compatible with RDX and AP. A reddish change occurred instantly when the cleaner was placed in contact with TNT.

Although no problems occurred during mixing or application, upon drying the cleaner was slick in appearance and slick to the touch. There was a noticeably low coefficient of friction to the surface, and unstable footing was a significant concern where the cleaner was used. In addition, streaks and mottling began to develop during extended evaluation. Wet mopping created an even more slippery surface during cleaning periods.

TABLE 3. Average Resistance and Resistance Reduction Achieved by Legclean Floor Cleaner.

Location[a]	Average[b] resistance, ohms	Average resistance[c] reduction, %	Type of measurement[d]		
			Before application	At application	After application
1	40M	. . .	E-E	. . .	. . .
	83K	99.79	. . .	E-E	. . .
	41K	99.90	. . .	E-G	. . .
	113K	99.72	. . .	. . .	E-E
	50K	99.88	. . .	. . .	E-G

[a] See Appendix C for corresponding building and room location.
[b] See Appendix F for raw data. M = 1,000,000 ohms; K = 1,000 ohms.
[c] The difference in resistance readings before and after application of floor coating is determined; then the percent of resistance reduction is calculated.
[d] E-G, electrode-to-ground measurement; E-E, electrode-to-electrode measurement.

CONDUCTIVE TOPPINGS

Cheminert

Cheminert is an organic topping, composed of two conductive base coats (liquid resins) and a mixture of Cheminert conductive powder and 610 conductive paste. No toxic or sparking characteristics were noted when several cured, laboratory-size samples provided by the company were evaluated. However, during mixing Cheminert may cause dermatitis in people sensitive to it, and appropriate precautions should be observed. Cheminert materials must be at 65°F or warmer prior to use and must be applied in areas where the temperature is 65°F or higher and remains so for four days after applications.

The Cheminert topping (Figure 6) was installed in April 1975, specifically to replace an existing conductive linoleum floor which did not meet the specifications outlined in Appendix A. Although resistance readings were found to be within the acceptable range, the linoleum was wrinkled, buckled and cracked in a number of places. Due primarily to concrete deterioration to some parts of the building floor when the linoleum topping was removed, a conductive paint or cleaner was not considered adequate.

Although newly installed, enough resistance data has been gathered on the Cheminert topping to draw some conclusions. Because the floor was laid down in layers, each layer was evaluated in

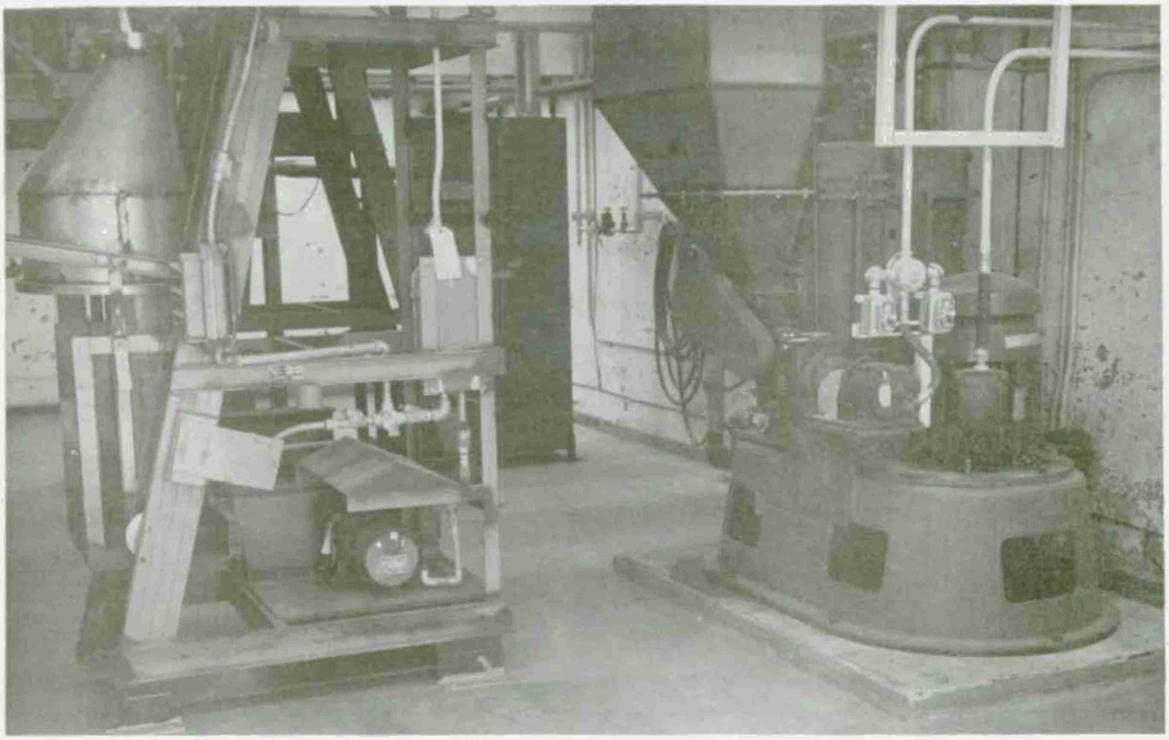

FIGURE 6. Cheminert Conductive Topping After Installation in a Grinding Bay.

TABLE 4. Average Resistance Achieved by Cheminert Floor Topping.

Location[a]	Average resistance,[b] ohms	Type of measurement[c]		
		Before application	At application	4 months after application
1	49K	E-G	...	...
	10K	...	E-E[d]	...
	10K	...	E-G[d]	...
	32K	...	E-E[e]	...
	10K	...	E-G[e]	...
	48K	...	E-E[f]	...
	28K	...	E-G[f]	...
	108K	...	...	E-E
	54K	...	...	E-G

[a] See Appendix C for corresponding building and room locations.
[b] See Appendix F for raw data. K = 1,000 ohms.
[c] E-G, electrode-to-ground measurement; E-E, electrode-to-electrode measurement.
[d] Measurements taken after addition of base coat resins.
[e] Measurements taken after addition of midlayer coating.
[f] Measurements taken after addition of topcoat.

both the electrode-to-electrode and the electrode-to-ground mode. Table 4 shows that the average resistance achieved by Cheminert immediately after the installation of all layers was 48,000 and 28,000 ohms for electrode-to-electrode and electrode-to-ground measurements, respectively. These are well within the resistance range required by existing regulations. Resistance reduction was not evaluated, since the previous flooring (linoleum) was not high in resistance, and in some areas even possessed lower resistance than the Cheminert.

Table 4 also indicates that after only four months of use, the average readings have essentially doubled; 108,000 ohms for electrode-to-electrode and 54,000 ohms for electrode-to-ground measurements. It is hoped that this trend does not continue and that a leveling off will soon occur. Future evaluative information will be supplied upon request as data becomes available.

In an 80°C oven-heat analysis, the Cheminert floor topping was found to be compatible with AP, HMX, and RDX. It should be noted, however, that TNT caused a black reaction in the center of the topping, with reddish discoloration around the black. In TNT processing buildings this apparent incompatibility would be a major concern. However, since TNT will not be processed in the building, the topping was given limited acceptability.

DISCUSSION

Several of the coatings proved to be effective for the hazardous conditions involved and merit consideration when future conductive flooring problems arise. However, in some instances the data is not sufficient. In others, conditions under which the data was obtained were probably not sufficiently designed or controlled to permit substantial correlation or analysis of the data.

Many variables were found that affect the adequacy or efficiency afforded by conductive coatings, even though the data summarized in this report was obtained from limited tests. In order to obtain future, more reliable information that can be applied over a wide variety of conditions, one must attempt to successfully control these variables. Variables that merit consideration are listed below and are covered under the general headings of installation, maintenance, factors influencing resistance measurements, traffic, and hazardous material compatibility. These variables are not considered to be all-inclusive.

INSTALLATION

Floor Preparation

Before coating an ordinary floor to create conductivity or to improve a malfunctioning conductive floor, the floor must be prepared in some fashion. In some cases the floor is steam-cleaned and subsequently dried. In other cases the floor is acid-etched (e.g., 50% hydrochloric acid, 50% water). Acid etching appears to create very good bonding due to its cleansing action on the surface to be coated. As a minimum, the floor may be only swept clean, or wet-mopped and then dried.

Floor Preparer

The knowledge and skill of personnel preparing the floor will certainly determine the degree of success one will have with a conductive coating (e.g., coating endurance, resistance fluctuation, adherence). If cost is no obstacle, it is desirable to request assistance from a manufacturing representative of the product, if not to lay the actual coating, at least to supervise its installation. If it is financially prohibitive to do this, then a facilities public works department or even personnel employed in the cognizant code may be called upon to do the job.

Coating Thickness

With most coatings, resistance can be varied by simply varying the coating thickness. This is not easily achieved since large fluctuations in resistance may occur as a result of only a 2- to 5-mil thickness differential.

Floor Type

Success or failure of a particular coating is dependent upon the type of floor onto which the coating is to be applied. Some coatings work exceptionally well on concrete, metal, or wood. Others may be designed to be used with vinyl or linoleum flooring. A thorough evaluation should be made prior to purchase.

MAINTENANCE

Floor Maintenance

The type of cleaning agent used on a floor after it has received a conductive coating must be controlled. Steam cleaning, solvent cleaning, wet mopping, and dry sweeping are only a few methods employed. Harsh agents will deteriorate a coated floor rapidly, but will provide substantial cleaning in most cases. On the other hand, weak agents will cause only minimal deterioration, but adequate cleaning may be sacrificed. Careful evaluation of the advantages and disadvantages of various cleaning agents is needed.

FACTORS INFLUENCING RESISTANCE MEASUREMENTS

Floor Preparation

Prior to conducting floor resistance measurements, the floor will be prepared in some manner, or not prepared at all. Dirt, grime, grease, and wax are just a few of the materials that may provide sufficient insulative effects to prevent reliable and accurate resistance readings if not removed from

the floor. However, cleaning the floor prior to conducting resistance measurements, may not simulate the floor resistance during normal working periods in which ordnance operations are being performed.

NAVSEA[1] requires that the room be cleaned before testing.

Frequency and Method of Cleaning

Cleaning a coated floor on a daily basis as opposed to a weekly or monthly basis, will probably cause a faster deterioration of the floor coating and thus create more drastic, less acceptable changes in resistance readings. The method of cleaning (wet mopping, steam cleaning, or dry sweeping) will also influence resistance measurements. If wet mopping or steam cleaning is the technique employed, the floor must be allowed to dry properly before resistance measurements are taken.

Humidity

Relative humidity must be controlled in order to obtain reliable resistance measurements over a period of time. A high humidity may cause enough moisture on the floor to affect the ohmmeter reading, causing the meter to show a lower resistance than there is normally. Similarly, a low humidity may cause an incorrect resistance indication. These readings may not reflect the average humidity conditions in the area. Therefore, maximum resistance should be determined under the driest condition and minimum resistance should be determined under the wettest condition.

Resistance Test Instruments

Resistance measurements in the electrode-to-electrode mode have proven to be higher, in some cases dramatically, than those in the electrode-to-ground mode. The former involves test current flowing from one electrode through the conductive surface to the other electrode, while the latter involves current flowing through the conductive surface to ground. Since the current has less distance to travel when going to ground than when going from one electrode to another (i.e., 3 feet), the resistance would be expected to be lower. It is postulated that this may be one of the major reasons for the difference in readings.

Two other reasons for differences in reading were noted. When two resistance-to-ground measurements were made at the same location, but with the leads interchanged between measurements, there was a noticeable difference between readings. Electrodes without a surface of tinfoil backed by a layer of rubber (i.e., nonresilient electrodes) provide readings significantly different in some cases from those provided by electrodes with the foil and rubber additions. Resilient electrodes give more valid and reliable measurements. They more nearly fit the contour of the floor being measured and thus allow not only more but also better surface area contact.

Several different types of ohmmeters are available for use in taking resistance measurements. Although all must operate on a nominal open-circuit output voltage of 500 volts DC, some meters are battery powered and have a tendency to drift. Others require hand cranking at a specified number of revolutions per minute (e.g., 160 rpm) to provide the correct readings. When compared, differences in readings between the above mentioned meters were found to be as large as 3,000 ohms and as little as 1,000 ohms.

Location of Readings

Resistance measurements taken at various places throughout the room should be located to approximate the normal traffic pattern. Readings taken in room corners having very little or nothing to do with ordnance operations, even though adequate from a requirement standpoint, are not appropriate. In addition, these readings when averaged with others taken around the room in question may effectively change an otherwise unacceptable floor to an acceptable floor, or vice versa.

TRAFFIC

Pedestrian Traffic

The amount of pedestrian traffic across a floor painted with a conductive coating needs to be determined, controlled, and evaluated as light, moderate, or heavy. Naturally, light traffic should lead to a better resistance and endurance evaluation over any given period of time than moderate or heavy traffic.

Materials Loading

The weight applied to a conductive coating and the manner in which it is applied affects endurance, deterioration, and thus resistance. As may be expected, light to moderate items with rubber wheels are less likely to damage a coating than heavy items with metallic wheels.

HAZARDOUS MATERIALS COMPATIBILITY

A single, yet satisfactory, method of determining and evaluating the compatibility or chemical reactivity of a particular conductive coating with propellant, high explosives, pyrotechnics or other high-energy materials must be determined and agreed upon. Currently, one method of evaluation is the 80°C oven-heat analysis, in which a coating sample is placed in physical contact with an explosives sample, usually in equal parts, left overnight in an 80°C oven, then analyzed for color changes and outgassing. Another method that is frequently used is a thermogram analysis, where exothermic changes, decomposition peak changes, and phase changes are analyzed for peculiarities. Neither method, however, indicates the extent or seriousness of the problem caused by the incompatibility. In addition, the degree to which these tests actually simulate everyday environmental conditions is not fully known.

SUMMARY

There does not appear to be sufficient information available at the present time to propose specific guidelines for using conductive coatings on malfunctioning conductive floors or ordinary

floors requiring a specific conductivity. The paints, cleaners, and toppings monitored and evaluated in this report may be used in setting up conductive flooring programs at other facilities, but the data should be evaluated cautiously. The data has been derived from limited tests conducted at the Naval Weapons Center, and although several coatings were found acceptable for the type of ordnance and explosives operations noted in Appendixes D, E, and F of this report, some variables probably did intervene to prevent a totally accurate analysis. It is readily apparent that research programs are needed to obtain data in which some of the aforementioned variables are controlled. It is hoped that this report will stimulate an interest in that direction.

Appendix A

EXCERPTS FROM *AMMUNITION AND EXPLOSIVES ASHORE SAFETY REGULATIONS FOR HANDLING, STORING, PRODUCTION, RENOVATION AND SHIPPING. VOLUME 1, FOURTH REVISION* (NAVSEA OP-5.)

The following excerpts are from Chapter 4, "Electrical Requirements."

4-7.2.4 CONDUCTIVE FLOORS

a. Specifications. Conductive floors may be made of lead, conductive rubber or plastic, conductive masonry material, or conductive composition material. Floors must comply with the following requirements:

(1) The surface of the floor must be free from cracks and reasonably smooth. If washing of floors is necessary, the material as installed must be capable of withstanding repeated washing with hot water. If conductive floors are to be waxed, a conductive wax which provides the same conductive characteristics shall be used.

(2) The material must not produce sparks when stroked briskly and firmly with a hardened steel file.

(3) The material must not slough off, wrinkle, or buckle under normal conditions of use.

(4) The resistance of the conductive floor shall be less than 1,000,000 ohms as measured between two electrodes placed three feet apart at any points on the floor. The resistance of the conductive floor to ground shall also be less than 1,000,000 ohms.

(5) The resistance of the floor shall be more than 5,000 ohms in areas with 110-volt service and 10,000 ohms in areas with 220-volt service, as measured between a permanent ground connection and an electrode placed at any point on the floor, and also as measured between two electrodes placed three feet apart at any points on the floor. This minimum is specified as an additional protection against electrical shock.

(6) Where conductive floors and conductive shoes are required, table tops on which exposed explosives or electroexplosive devices are handled or where explosive dust is encountered shall be covered with properly grounded, conductive, sparkproof material.

b. Use of Conductive Floors. Conductive floors are mandatory in areas where personnel work with or are exposed to contact with the materials listed in paragraphs 4-6.4.1 through 4-6.4.3 or other materials known to be static sensitive. Conductive shoes or other devices providing similar protection shall be worn in areas where conductive floors are mandatory. Sparkproof shoes should be worn in conjunction with steel reinforced concrete floors. Where the need for conductive floors is localized, they need not be installed throughout the building.

4-8.2.2 CONDUCTIVE FLOOR TESTING

a. General Requirements. Conductive floors shall be tested at time of installation and at least semiannually thereafter. In areas exposed to large variations in relative humidity, additional measurements should be made during times of lowest relative humidity and highest relative humidity to ensure adequate floor conductivity. The tests shall determine if the floors meet the requirements of paragraph 4-7.2.4a. The results of these tests shall be posted in a log and maintained on file.

b. Method of Test.

(1) The floor shall be clean and dry and the room shall be free of flammable gas mixtures or explosive dusts.

(2) Each electrode shall weigh five pounds and shall have a dry, flat, circular contact area 2-1/2 inches in diameter, which shall comprise a surface of aluminum or tinfoil 0.0005 to 0.001 inch thick, backed by a layer of rubber 1/4 inch thick and measuring between 40 and 60 durometer hardness as determined with a Shore Type A durometer (ASTM D-2240–68).

(3) Resistance shall be measured with a suitably calibrated ohmmeter which shall operate on a nominal open-circuit output voltage of 500 volts DC and a short-circuit current of 5 millamperes with an effective internal resistance of 100,000 ohms ±10%.

(4) For both electrode-to-electrode and electrode-to-ground, measurements shall be made at five or more locations in each room and the results averaged. For compliance with paragraph 4-7.2.4a (4), the average shall be below the limits specified and no value shall be greater than five megohms. For compliance with paragraph 4-7.2.4a (5), no location shall have a resistance less than that specified. Where resistance to ground is measured, two measurements shall be made at each location, with the test leads interchanged at the instrument between measurements; the average of the two measurements is to be taken as the resistance to ground at that location. All readings may be taken with the electrode or electrodes more than three feet from any ground connection or grounded object resting on the floor. If the resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about five seconds shall be considered to be the measured value.

c. Use of Test Instruments. Instruments for testing the conductivity of floors shall be used inside the room only if the room is free of explosives and no exposed electroexplosive devices are present; otherwise, the test instrument shall be placed outside the room. In any case, the floor in the immediate area of the electrode contact shall be thoroughly cleaned of all explosive material and the air purged of explosive dust or vapors.

Appendix B

MANUFACTURING COMPANY AND ADDRESS FOR COATINGS EVALUATED

1. Elimstat LX-23
   Walter G. Legge Co., Inc.
   101 Park Ave.
   New York, N.Y. 10017
2. Phenoline 304 Conductafloor
   Carboline Co.
   350 Hanley Industrial Court
   St. Louis, Mo. 63144
3. Groundzol #6890
   Gilmore and Nolan
   (Division of Bee Chemical Co.)
   1500 W. 178th St.
   Gardena, Calif. 90247
4. Conducote
   Walter G. Legge Co., Inc.
   101 Park Ave.
   New York, N.Y. 10017
5. Legclean
   Walter G. Legge Co., Inc.
   101 Park Ave.
   New York, N.Y. 10017
6. Conductive Cheminert
   Crossfield Products Corp.
   3000 East Harcourt St.
   Compton, Calif. 90221

Appendix C

TABLE C-1. Building and Room Locations Used in Coating Evaluations.

Buildings located in Propulsion Development Department, NWC.

No.	Building	Room
Groundzol #6890 Floor Paint		
1	10030	101/102
2	10090	121
3	10640	107
4	15540	101
5	15590	101
6	15741	101
7	16085	1
Elimstat LX-23 Floor Paint		
1	10090	125
2	10200	123
3	10570	116
4	10580	114
5	15743	101
6	31576	1
Legclean Floor Cleaner		
1	15524	101
Cheminert Floor Topping		
1	15980	1

Appendix D

TABLE D-1. Evaluation of Locations Used for Testing of Groundzol #6890 Conductive Floor Paint.

All floors are concrete.

Location[a]	Material(s) handled and operations	Floor preparation prior to application	Traffic		Floor maintenance after application
			Pedestrian	Materials loading	
1	Electroexplosive devices handling and testing	Dry-swept, steam-cleaned, air-dried	Light	(None)	Dry sweeping, wet (H_2O) mopping, air drying
2	Electroexplosive devices handling and assembly	Dry-swept, water-mopped, air-dried	Light	(None)	Dry sweeping
3	Fuel-air explosive (FAE) weapon assembly	Dry-swept, steam-cleaned, air-dried	Moderate	Moderate	Dry sweeping
4	Warhead assembly, Explosive aging	Acid-etched (50% HCl, 50% H_2O), water-mopped, air-dried	Moderate	Moderate	Dry sweeping
5	Explosive melting and casting	Acid-etched (50% HCl, 50% H_2O), water-mopped, air-dried	Moderate	Moderate	Wet (H_2O) mopping, air drying
6	Composite propellant mixing	Dry-swept, steam-cleaned, air-dried	Heavy	Heavy	Dry sweeping, wet (H_2O) mopping, air drying
7	Pyrotechnic mixing	Dry-swept, steam-cleaned, air-dried	Light	Light	Dry sweeping

[a] See Appendix C for corresponding building and room locations.

TABLE D-2. Resistance Measurements of Floors Coated with Groundzol #6890.

Location[a]	Resistance measurements[b] at 6 places						Type of measurement[c]			Date of measurement
	1	2	3	4	5	6	Before application	At application	After application	
1	100M	100M	100M	100M	100M	100M	E-G	. . .	. . .	4-26-73
	200K	100K	50K	100K	100K	100K	. . .	E-G	. . .	8-6-73
	1.5M	300K	300K	300K	200K	150K	. . .	. . .	E-E	1-29-75
	200K	100K	100K	100K	100K	60K	. . .	. . .	E-G	1-29-75
2	100M	100M	100M	100M	100M	100M	E-G	. . .	. . .	6-3-70
	300M	200K	150K	400K	100K	200K	. . .	E-G	. . .	8-10-71
	300K	250K	200K	250K	50K	150K	. . .	. . .	E-G	4-23-73
3	20M	40M	60M	12M	100M	20M	E-G	. . .	. . .	9-28-72
	3M	1.5M	500K	3M	1.5M	300K	. . .	E-E	. . .	11-13-73
	700K	100K	75K	700K	100K	100K	. . .	E-G	. . .	11-13-73
	200K	600K	2M	300K	600K	500K	. . .	. .	E-E	1-3-75
	125K	125K	500K	100K	175K	100K	. .	. . .	E-G	1-3-75
4	1M	1M	1M	1M	1M	1M	E-G	. . .	. . .	8-10-73
	300K	150K	300K	150K	300K	300K	. . .	E-E	. . .	10-11-73
	150K	50K	100K	50K	50K	50K	. . .	E-G	. . .	10-11-73
	100K	150K	175K	150K	250K	175K	. . .	. . .	E-E	10-3-74
	50K	75K	75K	50K	75K	100K	. . .	. . .	E-G	10-3-74
5	1.5M	50K	200K	100K	900K	3M	E-G	. . .	. . .	11-21-73
	50K	50K	50K	65K	100K	10K	. . .	E-G	. . .	11-26-73
	75K	150K	100K	150K	200K	100K	. . .	. . .	E-E	10-4-74
	100K	75K	75K	75K	100K	75K	. . .	. . .	E-G	10-4-74
6	40M	4M	50M	75M	75M	4M	E-G	. . .	. . .	1-12-71
	600K	200K	10K	600K	100K	400K	. . .	E-G	. . .	6-25-73
	15M	10K	50K	15M	15M	10K	. . .	. . .	E-E	5-31-74
	2M	10K	30K	1.5M	800K	10K	. . .	. . .	E-G	5-31-74
7	100M	100M	100M	100M	100M	100M	E-G	. . .	. . .	12-19-72
	800K	100K	600K	200K	200K	200K	. . .	E-G	. . .	12-7-73
	700K	100K	200K	200K	200K	150K	. . .	. . .	E-E	1-29-75
	150K	50K	75K	50K	50K	50K	. . .	. . .	E-G	1-29-75

[a] See Appendix C for corresponding building and room locations.
[b] M = 1,000,000 ohms; K = 1,000 ohms.
[c] E-G, electrode-to-ground measurement; E-E, electrode-to-electrode measurement.

Appendix E

TABLE E-1. Evaluation of Locations Used for Testing of Elimstat LX-23 Conductive Floor Paint.

All floors are concrete.

Location[a]	Material(s) handled and operations	Floor preparation prior to application	Traffic		Floor maintenance after application
			Pedestrian	Materials loading	
1	Electroexplosive devices handling and assembly	Dry-swept, steam-cleaned, air-dried	Light	(None)	Dry sweeping
2	Igniter loading and assembly	Dry-swept, steam-cleaned, air-dried	Light	(None)	Dry sweeping
3	Composite propellant machining and milling	Dry-swept, steam-cleaned, air-dried	Moderate	Moderate	Dry Sweeping, wet (H_2O) mopping, air drying
4	Composite propellant machining	Dry-swept, steam-cleaned, air-dried	Moderate	Moderate	Dry sweeping, wet (H_2O) mopping, air drying
5	Composite propellant processing	Dry-swept, steam-cleaned, air-dried	Moderate	Moderate	Dry sweeping, wet (H_2O) mopping, air drying
6	Fuze assembly	Dry-swept, steam-cleaned, air-dried	Light	Light	Dry sweeping, wet (H_2O) mopping, air drying

[a] See Appendix C for corresponding building and room locations.

TABLE E-2. Resistance Measurements of Floors Coated with Elimstat.

Location[a]	Resistance measurements[b] at 6 places						Type of measurement[c]			Date of measurement
	1	2	3	4	5	6	Before application	At application	After application	
1	100M	100M	100M	100M	100M	100M	E-E	...	...	4-23-73
	10K	10K	10K	10K	10K	10K	...	E-E	...	12-17-73
	10K	10K	10K	10K	10K	10K	...	...	E-E	1-29-75
	10K	10K	10K	10K	10K	10K	...	...	E-G	1-29-75
2	100M	100M	100M	100M	100M	100M	E-G	...		12-10-73
	10K	10K	10K	10K	10K	10K	...	E-G	...	12-15-73
	25K	150K	40K	40K	25K	40K	...	...	E-E	1-30-75
	15K	15K	15K	15K	15K	15K	...	...	E-G	1-30-75
3	100M	100M	100M	100M	100M	100M	E-E	...	...	9-4-73
	100M	100M	100M	100M	100M	100M	E-G	...	...	9-4-73
	10K	10K	10K	10K	10K	10K	...	E-E	...	12-10-73
	10K	10K	10K	10K	10K	10K	...	E-G	...	12-10-73
	40K	50K	40K	50K	50K	50K	...	...	E-E	12-27-74
	10K	10K	10K	10K	10K	10K	...	...	E-G	1-22-75
4	100M	100M	100M	100M	100M	100M	E-E	...	...	9-17-73
	100M	100M	100M	50M	50M	100M	E-G	...		9-17-73
	10K	10K	10K	10K	10K	10K	...	E-G		12-15-73
	20K	20K	30K	25K	200K	20K	...	...	E-E	1-27-75
	10K	10K	10K	10K	10K	10K	...	...	E-G	1-27-75
5	100M	100M	100M	100M	100M	100M	E-G	...	...	1-12-73
	10K	10K	10K	10K	10K	10K	...	E-G	...	12-8-73
	20K	20K	20K	20K	20K	20K	...	...	E-E	1-23-75
	10K	10K	10K	10K	10K	10K	...	...	E-G	1-23-75
6	1M	1M	1M	1M	1M	1M	E-G	...	...	7-12-73
	10K	10K	10K	10K	10K	10K	...	E-G	...	1-21-74
	10K	10K	100K	100K	100K	100K	...	...	E-E	3-17-74
	10K	10K	10K	10K	70K	70K	...	...	E-G	3-17-74

[a] See Appendix C for corresponding building and room locations.
[b] M = 1,000,000 onms; K = 1,000 ohms.
[c] E-G, electrode-to-ground measurement; E-E, electrode-to-electrode measurement.

Appendix F

TABLE F-1. Evaluation of Locations Used for Testing of Legclean and Cheminert.

All floors are concrete.

Location[a] and product used	Material(s) handled and operations	Floor preparation prior to application	Traffic		Floor maintenance after application
			Pedestrian	Materials loading	
1[a] Legclean, conductive floor cleaner	High explosive processing and machining	Dry-swept, wet (H_2O) mopped, air-dried	Light	Light	Dry sweeping, wet (H_2O) mopping, air drying
1[b] Cheminert, conductive floor topping	Ammonium perchlorate grinding, high explosive particle size reduction	Conductive linoleum tile removed, cracks and crevasses filled	Medium	Light	Dry sweeping, wet (H_2O) mopping, air drying

[a] See Appendix C (Building 15524, Room 101).
[b] See Appendix C (Building 15980, Room 1).

TABLE F-2. Resistance Measurements for Floor Cleaned with Legclean.

Location[a]	Resistance measurements[b] at 6 places						Type of measurement[c]			Date of measurement
	1	2	3	4	5	6	Before application	At application	After application	
1	100M	10K	20M	100M	300K	20M	E-E	. . .	. . .	4-11-73
	100K	100K	50K	50K	100K	100K	. . .	E-E	. . .	9-25-73
	10K	75K	25K	50K	75K	10K	. . .	E-G	. . .	9-25-73
	200K	150K	75K	75K	75K	100K	. . .	. . .	E-E	10-3-74
	50K	50K	50K	50K	50K	50K	. . .	. . .	E-G	10-3-74

[a] See Appendix C (Building 15524, Room 101).
[b] M = 1,000,000 ohms; K = 1,000 ohms
[c] E-G, electrode-to-ground measurement; E-E, electrode-to-electrode measurement.

TABLE F-3. Resistance Measurements for Floor Topped with Cheminert.

Location[a]	Resistance measurements[b] at 6 places						Type of measurement[c]			Date of measurement
	1	2	3	4	5	6	Before application	At application	After application	
1	50K	50K	50K	50K	50K	45K	E-G	. . .	. . .	11-21-73
	10K	10K	10K	10K	10K	10K	. . .	E-E[d]	. . .	4-10-75
	10K	10K	10K	10K	10K	10K	. . .	E-G[d]	. . .	4-10-75
	30K	40K	30K	30K	30K	30K	. . .	E-E[e]	. . .	4-11-75
	10K	10K	10K	10K	10K	10K	. . .	E-G[e]	. . .	4-11-75
	45K	50K	50K	50K	50K	45K	. . .	E-E[f]	. . .	4-14-75
	30K	30K	30K	30K	30K	20K	. . .	E-G[f]	. . .	4-14-75
	100K	100K	150K	100K	100K	100K	. . .	. . .	E-E	8-8-75
	50K	50K	50K	50K	75K	50K	. . .	. . .	E-G	8-8-75

[a] See Appendix C (Building 15980, Room 1).
[b] K = 1,000 ohms.
[c] E-G, electrode-to-ground measurement; E-E, electrode-to-electrode measurement.
[d] Measurements taken after addition of base coat resins.
[e] Measurements taken after addition of midlayer coating.
[f] Measurements taken after addition of topcoat.

Nomenclature

Thermogram analysis	Comparative analysis of exotherms, decomposition peak changes, and phase changes during the time that the conductive coating and explosive material are separate and in intimate contact
80°C oven-heat analysis	Analysis of color changes, outgassing, and fuming during the time that the conductive coating and explosive material are in intimate contact within an 80°C oven
MEG or M	1,000,000 ohms resistance
K	1,000 ohms resistance
Al	Aluminum
AP	Ammonium perchlorate
HMX	Cyclotetramethylenetetranitramine
RDX	Cyclotrimethylenetrinitramine
TNT	Trinitrotoluene
CTPB	Carboxyterminated polybutadiene binder
HCl	Hydrochloric acid
H_2O	Water
Viton	Fluorohydrocarbon binder
°C	degrees Celsius
°F	degrees Fahrenheit

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